

# Forensic veterinary evaluation of injuries caused by a shot with a smoothbore weapon in domestic dogs

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### Summary

Gunshot injuries in animals are an important subject of forensic veterinary expert opinions. The common occurrence of shootings with hunting weapons in veterinary and forensic practice and the need to determine their cause and effects and to identify the ammunition used, make it necessary to investigate characteristic features of injuries caused by various types of ammunition. This experiment involved shooting research material, i.e. nine carcasses of domestic dogs, with various calibres from distances of 0 m (contact shot), 1.2 m and 10 m. Pellets with diameters of 2.4 mm or 8.45 mm and slugs were used to obtain the full spectrum of injuries that may result from a shot with a smoothbore weapon. Next, colour tests were performed to identify gunshot residues in the area of the wound, as well as imaging tests, i.e. X-ray and CT, necropsy and a histopathological examination of tissues around the entry wound. The results reveal the possibility of extensive injuries to the tissues and bones of victims of gunshot wounds. A thorough analysis of the results of the experiment with projectiles of various calibres indicates that the extent and location of the damage are correlated with the calibre, diameter and body mass of the pellets, their initial velocity and the distance between the end of the barrel and the object shot.

**Keywords:** forensic veterinary medicine, gunshot injuries, X-Ray, PMCT, necropsy

Owing to the dynamic development of veterinary forensics in Poland in recent years, forensic veterinary expert opinions currently play an important role in proceedings carried out by judicial bodies. Preliminary and judicial proceedings often involve a forensic veterinary assessment of the consequences of an act and determination of the circumstances of various types of mechanical injuries to an animal's body. One distinctive type of mechanical injury is a gunshot wound.

Among small arms, hunting weapons are a special and very important group, especially in the context of forensic veterinary medicine. According to ammunition used for hunting, a weapon with a smoothbore barrel or barrels is called a shotgun, while a rifled bore firearm is called a rifle. The effect of a shot fired using shot ammunition is achieved through the shock induced when the target is struck by a sufficient quantity of pellets with sufficient kinetic energy. The hunter's choice of a cartridge with a specific thickness and number of pellets depends on practical needs. For short-range shots, a cartridge with a smaller shot load is a suitable choice because it makes it possible to

evenly cover the target with a wider spread of pellets. A better choice for large distances is a more powerful shot load, which significantly reduces the scattering of pellets. Therefore various pellet diameters are used in hunting, depending on what type of game is targeted (12). A specific and very distinctive group in hunting comprises ball cartridges intended for shooting from smooth barrels, created to improve the accuracy of smoothbore ammunition.

Gunshot wounds in animals are an important subject of forensic veterinary expert opinions. Most cases of unintentional gunshots in veterinary medicine occur during hunting, when hunters mistakenly shoot at an unintended target. The victim in this case may be a hunting dog or animal of similar size and colouring as the target. Intentional shooting of animals most often takes the form of poaching. This is activity in violation of the Hunting Law, which clearly defines poaching as activity aimed at obtaining game in a manner which is not hunting, in violation of conditions specified in Art. 4 Section 2 of the Act on the Admissibility of Hunting. Poaching acts meet the criteria of a crime,

that is, the illegal possession of a firearm, and above all, killing of animals with particular cruelty, which, according to the Animal Protection Act, is punishable by fine or imprisonment. Another large category comprises shooting of animals in connection with criminal activity. This takes place when an animal, most often a dog, presents an obstacle for the criminal. A specific category of intentional shooting of animals, defined in Art. 35 of the Animal Protection Act of 1999, involves abuse and killing of animals. These are cases of people displaying aggression towards their environment, which often takes the form of violence against a dog (4, 7, 18).

Because of the special type of damage to the body, gunshot injuries require detailed diagnostics (in living victims and post-mortem) and specialized surgical procedures, as well as physical rehabilitation. The mechanism by which these injuries arise is extremely complex and depends mainly on the type of the firearm used, the type and velocity of the ammunition, and the angle and distance at which the shot was fired. Using specialized tests, the expert veterinarian is able to determine the characteristic features and extent of injuries in the victim's body and to establish the cause and likely circumstances of the death. This information is of fundamental importance for the conduct of proceedings by procedural authorities.

The empirical part of this study presents methods for a thorough analysis of wounds caused by shooting with a hunting weapon. Despite belonging to the same group, injuries caused by this type of weapon can be extremely diverse. Therefore the need arose for a comparative analysis of injuries caused by specific types of ammunition, additionally taking into account differences in distance, in order to eliminate errors in expert forensic veterinary opinions. The specific nature and usefulness of various methods was compared: tests based on chemical colour reactions, radiological methods, i.e. X-ray and computed tomography, histopathology, as well as the traditional method of macroscopic examination (necropsy) of the carcass of an animal (a dog).

### Material and methods

The material for the study were carcasses of mixed-breed domestic dogs obtained from amateur breeding and kept as companion animals. The animals were euthanized due to advanced age and age-associated health problems or a generalized, progressive disease process with an unfavourable prognosis. The procedure was carried out by intravenous injection of pentobarbital with the owners' consent.

The varied ammunition used in the experiment made it possible to obtain a wide-ranging pattern of gunshot wounds, despite the use of only one gun – a smoothbore shotgun.

The experiment was divided into stages. The first stage involved firing at the research material from distances of 0 m (contact shot), 1.2 m and 10 m. Characteristics of the

Tab. 1. Ammunition used in the experiment

Manufacturer	Hunting ammunition factory Pionki (Pionki, Poland)		
	12/70	Loftka SG Kal. 12/70	Original Brenneke Magnum 12/76
Projectile calibre	12/70	Loftka SG Kal. 12/70	Original Brenneke Magnum 12/76
Shot diameter [mm]	2.4	8.45	N/A
Shot weight [g]	24	29	39
Velocity $V_{2.5}$ [m/s]	390	400	390

Tab. 2. Characteristics of the material and ammunition and the range of shot

No of dog	Sex	Weight [kg]	Projectile calibre	Type of cartridge	Shot distance [m]
1	F	30.7	.12	2.4 mm	0
2	F	39.0	.12	8.45 mm	0
3	M	38.0	.12	slug	0
4	F	34.0	.12	2.4 mm	1.2
5	M	32.4	.12	8.45 mm	1.2
6	M	46.8	.12	slug	1.2
7	F	28.8	.12	2.4 mm	10
8	F	34.3	.12	8.45 mm	10
9	M	17.4	.12	slug	10

ammunition used and the research material are presented in Tables 1 and 2.

Each carcass was shot twice. The first shot was perpendicular to the frontal bone in the direction of the occiput, and the second was perpendicular to the body in the direction of the right scapula.

The next stage was the analysis of the gunshot wounds. First, chemical colour reactions were used to establish the presence of gunshot residue in the form of metal ions near the entry wound. The metals analysed were iron, copper, zinc and lead, used to manufacture structural elements of the projectile or the barrel of the gun. Individual ions were revealed using an appropriate electrolyte as well as reagents inducing characteristic colour reactions. Macroscopic analysis of the change in the colour of the gunshot residue on self-adhesive film revealed the presence or absence of the ions (qualitative analysis). The colour intensity of the samples was compared for quantitative assessment of individual ions, associated with the distance between the muzzle and the object that was shot.

The next part of the experiment involved X-raying the material. This was done using the Agfa DX-D 600 radiography system with a caesium iodide (CsI) detector ensuring high-quality images and Musica 3 software for processing the images. The software automatically selects processing parameters with automatic dose control and an algorithm for optimizing image quality, ensuring a higher image quality and visibility of diagnostic details. The images were made in lateral-lateral projection.

The next step consisted of tomographic analysis using the 16-row Astelion Advance Edition tomography system. CT scans were made in high resolution acquisition at 0.5 mm slice intervals and imaging area adjusted to the size of the animal to obtain an optimal pixel size under 0.5 mm.

Current parameters: standard anodes – 120 kV, active iterative reconstruction function and the use of filters to improve image quality in the case of foreign bodies (ammunition or fragments). 3D reconstructions were created – SSD surface and VRT spatial – with visualization of metallic foreign bodies – projectiles (shown in red).

The final step was necropsy examination of the material. Entry wounds from the shots were revealed, together with an abrasion collar, grease collar, fouling area and gunpowder tattoo. Exit wounds were located when possible. Elements sought in particular were fractures and the wound track together with the surrounding contusion zone. In the case of perforating wounds, the wound track was probed with forceps, and visual reconstruction of the track was performed. Foreign bodies were extracted from the tissue, including projectiles and projectile fragments, as well as structural elements of the cartridges.

The final stage consisted of histopathological examination of tissues from the vicinity of the entry wound. The material was collected during necropsy and then fixed and stained according to the procedure for H&E-stained slides.

## Results and discussion

Owing to the specific nature of veterinary forensics as a scientific discipline, its subject matter does not directly include issues of animal protection. However, the practical application of this branch of knowledge allows private individuals and especially procedural bodies to implement animal protection. According to Listos et al. (3), this science deals with establishing the cause-and-effect sequences leading to the occurrence of injuries on an animal's body and the cause of the animal's death. Pathological changes revealed by the examination can significantly facilitate legal proceedings and lead to the disclosure of material truth.

Animals are usually shot during reported and approved hunting, and any other use of a firearm against an animal is a criminal act regulated by Art. 35 of the Act of 21 August 1997 on Animal Protection, Journal Laws of 2023, item 1580.

Forensic veterinary expert opinions regarding gunshot wounds are also used for establishing the course of an event by answering questions posed by procedural authorities. It is therefore extremely important for an expert veterinarian to prepare a thorough and reliable opinion, for which it is necessary to secure gunshot residues and bullets or their fragments. Entry and exit wounds and bullet tracks in degraded tissue will be revealed, and the cause of the animal's death will be determined. The results of the present study indicate that additional tests are useful in obtaining this information and are an extremely valuable source in legal proceedings.

The experiment described here involved shooting the carcasses of nine domestic dog using various calibres from distances of 0 m (contact shots), 1.2 m and 10 m. The results demonstrate the possibility of extensive injuries in the tissues and bone of gunshot victims, which

are the most common cases in which expert opinions are issued in forensic veterinary practice (3). A more in-depth analysis of the results of the experiment using ammunition of various calibres shows that the extent and location of damage are correlated with the calibre, initial velocity, and kinetic energy of the projectile, as well as the distance between the muzzle and the target.

According to our observations, the extent of a wound depends on the distance from which the shot was fired, the physical properties of the ammunition and the part of the body shot.

The assessment of gunshot wounds requires the analysis of the entry wound and, if possible, the exit wound. The present study showed a relationship between the propellant and the extent of these wounds. This can be seen in the case of a shot from a .12 calibre shotgun. A contact shot, in each case tested, using shot with a diameter of 2.4 mm or 8.45 mm or a slug, caused an entry wound image similar to that of a wound caused by a ball cartridge. The distance from which the shot was fired was too short for the pellets to spread, so the concentrated pellets, with a large portion of kinetic energy, penetrated the tissue like a fixed cartridge. Only after entering the body did the pellets rapidly lose energy and become separated and distributed irregularly in the tissues.

In the case of material no. 1, 2, 3, and 4, it was also possible to determine the distance from which the shot was fired during necropsy by finding plastic wads – components of shot shells, which did not show any shading during imaging analysis. The structural elements of projectiles extracted during the examination are shown in Figure 4. These elements are meant to keep individual pellets together during the first phase of the shot. During firing, they lose kinetic energy very quickly and fall to the ground at a short distance from the muzzle, while the released pellets begin to disperse in the air or in the penetrated material. Finding foreign bodies indicates that the shot was fired at close range, since they had enough energy to penetrate the skin and become lodged in the tissues. Thus it can be concluded that it was a contact shot or a shot fired at close range.

In forensic veterinary medicine, examination of the grease collar and fouling area is very difficult due to the dark colour of the hair coat of animals. Nevertheless, in the case of the contact shot with .12 8.45 mm buckshot pellets (material no. 2), a grease collar, a fouling area and singed hair coat surrounding the entry wound were visible. Classical burns were not observed, because the experiment was not conducted on living material. Hence, the results show differences in the appearance of gunshot wounds depending on the distance from which the shot was fired, because the presence of a grease collar and fouling around the entry wound conclusively indicates a contact shot or a shot fired at a very close range.

The experiment revealed that a shot to the head with .12 ammunition from a distance of 0 or 1.2 m caused entry wounds similar to those caused by a shot with a ball cartridge, but with a diameter exceeding that of such wounds. This is undoubtedly due to the large diameter of the cartridge, and thus the diameter of the shot spread. After piercing the skull bone, the pellets were spread so that each one moved with its own energy along its own flight path, causing complete degradation of the nervous tissue and glial tissue of the brain. Following the loss of energy, most of the pellets were lodged in the occipital and cervical parts of the material. A different situation occurs in the case of shooting with a shot cartridge with a pellet diameter of 2.4 mm from a distance of 10 m, leading to the presence of numerous projectiles in the form of birdshot pellets in the subcutaneous and muscle tissue in the area where the material was shot. In this case (material no. 7), no damage to the bone, that is, ribs, spine or skull, or to the nervous or glial tissue of the brain was observed. It can be concluded that a shot to a living victim in these parts of the body need not result in sudden and immediate death. It seems highly likely, however, that it would cause numerous injuries to the animal.

In the case of a suspected gunshot, a test for the presence of metal ions – gunshot residue (GSR) – can be performed at the site where the body is discovered or during autopsy. The technical and analytical aspects of GSR analysis are mostly internationally standardized, in contrast with the interpretation of the results, which does not depend on standards dictated from above, but on the expert's own interpretation. This is because the results may be influenced by factors related to the type of event, the site and means of collection of the material or even atmospheric conditions at the site of the event.

Turillazzi et al. (17) conducted an analysis of GSR based on an experiment on samples of pig skin. Morphological examination of GSR particles was conducted after non-specific staining of the residue with sodium rhodizonate in combination with ICP-AES analysis. It was determined that, as the shooting distance increased, lead in the vicinity of the entry wound became more difficult to detect, until a negative reaction with sodium rhodizonate was obtained at 100-150 cm. Similar results on the usefulness of sodium rhodizonate in determining the distance of a shot were reported by Tugcu (16). As the range increased, the amount of GSR particles around the entry wound was found to decrease, which was confirmed in the present study, in which lead particles appeared in the case of a contact shot (Fig. 1) and were found sporadically in the case of a shot from a distance of 1.2 m, but were impossible to detect following a shot from 10 m.

In the present study, the presence of copper particles as elements of the casing and jacket was not detected for any distance or type of ammunition.



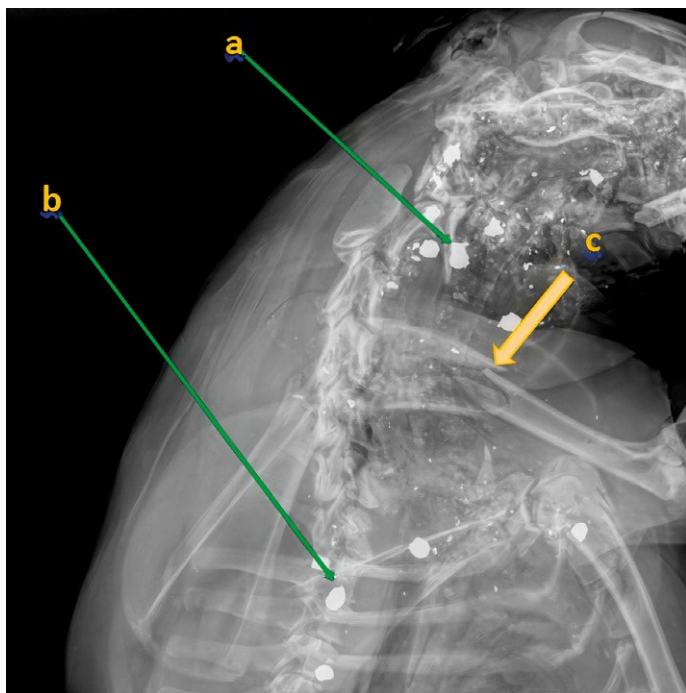
**Fig. 1. Positive result for lead in a colour test for the presence of characteristic elements following a contact shot with .12 8.45 mm buckshot**

In summary, analyses of GSR provide the basis for determining the extent of the occurrence of individual metallic particles deposited on the test material following a gunshot. The presence of fouling, burns and particles of unburned gunpowder together with numerous metallic particles from the cartridge or the weapon suggests a contact shot or a shot at a very close range. In contrast, a substantial presence of metallic particles without soot or burns indicates a distance of about 50-120 cm from the muzzle. This conclusion made it possible to distinguish an additional range of distances from which the shots were fired on the basis of the physicochemical distribution of the gunshot residue on objects that had been shot through.

Analyses of gunshot injuries, in both living victims and post mortem, are expanded to include radiological methods if the necessary equipment is available. Many scientific reports on this subject conclusively demonstrate the usefulness of these methods in the analysis of gunshot injuries. Wüllenweber et al. (23) conducted an analysis of gunshot wounds to the head using X-rays and CT and found both methods to be very useful. Schumacher et al. (10) also tested the usefulness of tomographic images, comparing the results with changes observed during autopsies. Their observations confirmed that both methods of examining gunshot injuries were in agreement.

Radiological imaging methods have proven important in forensic assessment of injuries when traditional macroscopic examination is difficult or impossible. For example, these methods are useful when the victim is suspected to have had an infectious disease or the body is in an advanced state of decomposition.

A significant advantage of radiological examination is that foreign bodies lodged in the victim's tissues can be more precisely revealed than in autopsy. In the case of a gunshot, this refers to projectiles or their fragments remaining in the tissues, sometimes even after most of the projectile has shot through the material. This is important because preparing a forensic veterinary expert opinion requires foreign bodies to be extracted



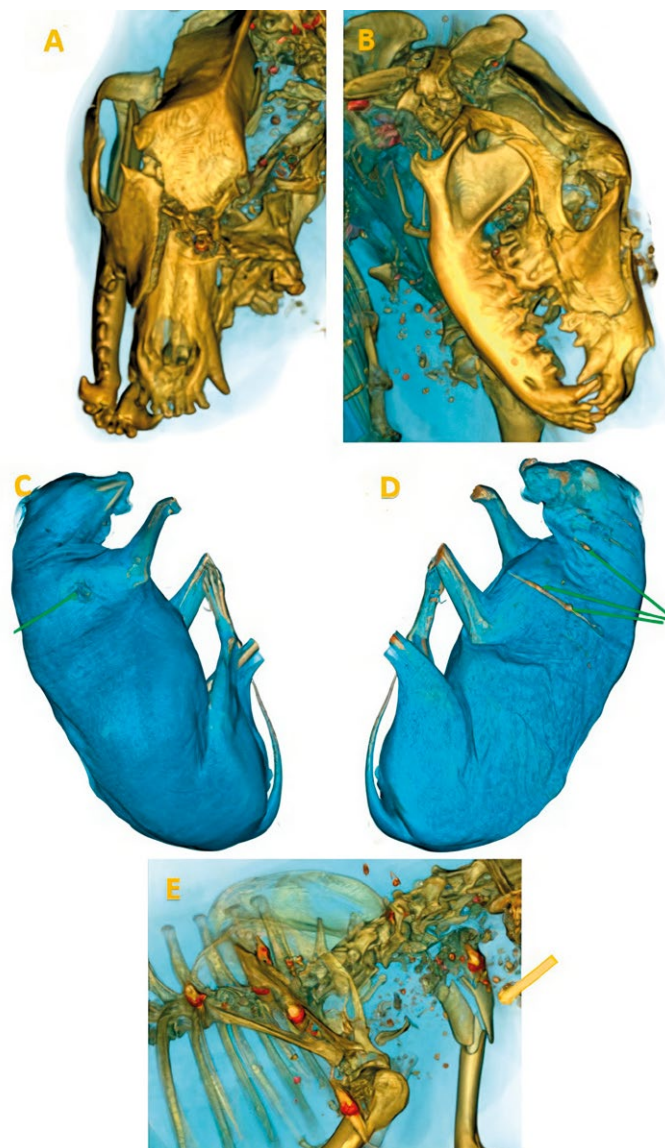
**Fig. 2. X-ray after contact shots with .12 8.45 mm buckshot**  
 Explanations: a – deformed pellets following a shot to the head; b – deformed pellets following a shot to the chest; c – humerus fracture

from the victim's tissues, so that they can be passed on to the authority which ordered the examination and for ballistics analysis. Taking radiographs and precisely locating projectiles or their fragments makes them easier to find during autopsy, which is often impeded by substantial degradation of soft tissues and bones in the area of the wound track. The usefulness of radiography in searching for foreign bodies and in detecting fractures is illustrated by the example presented in Figure 2, which shows an image following a contact shot with ammunition 8.45 mm in diameter. Location of foreign bodies by computed tomography is unquestionably more precise than it is by radiography, which was confirmed in the present study. Whole projectiles in their original or deformed shape were revealed in material no. 1, 2, 4, 5, 7 and 8, while only fragments spread through the tissues were shown in materials 3, 6 and 9. Metallic elements found during necropsy are shown in Figure 4.

According to Thali et al. (13-15), radiography does not afford a precise analysis of gunshot injuries, because it produces only a two-dimensional image. The authors conducted a retrospective analysis of the case of eight people with gunshot wounds. Apart from radiography, they also performed multi-slice computed tomography (MSCT) and MRI. Based on the data obtained in the form of a series of 2D and especially 3D images, they were able to detect fractures of the skull bone and brain injuries, including the wound track and displaced bone fragments, which are difficult to detect by radiography. The results were compared with the autopsy image, and all tests were shown to be in agreement.

The present study confirmed the conclusions drawn from studies by many researchers, including Madhu et al. (5) and Woźniak et al. (20-22), which showed that CT can be used for effective 3D reconstruction of a model of the test material. This improves the imaging of damaged bone fragments and the remains of foreign bodies, such as bullets, in tissues.

Imaging analysis is also useful in identifying injuries in places that are difficult to access during traditional autopsy, such as soft tissues, the base of the skull and the back of the neck. This is confirmed by Scaparra et al. (8, 9) and by Maiese (6) for gunshot injuries in these parts of the body. Analysis of gunshot injuries by computed tomography of the head makes it possible to identify skull fractures. However, Woźniak et al. (22), in a comparative study of 10 people with gunshot wounds to the head, found high agreement



**Fig. 3. CT visualization following contact shots with .12 8.45 mm buckshot**

Explanations: A, B – shot to the head; C – shot to the chest from the right, entry wound marked; D – shot to the chest, exit wounds on the side of the left scapula, E – contrasting foreign bodies, humerus fractures marked

in 30% of cases and only partial agreement in 70% of cases between the autopsy image of the fractures and CT reconstruction. It was concluded that these differences may have been due to insufficiently thin cross-sections made during computed tomography, but this effect is eliminated during the post-mortem analysis of the victim (PMCT – post mortem computed tomography), which involves more cross-sections and longer exposure to radiation. According to Donchin et al. (1), PMCT can reduce or even eliminate errors in expert opinions based exclusively on autopsy. In addition, the present study showed that performing classic autopsy and post-mortem tomographic analysis provided a more precise image of pathological changes. PMTC made it possible to find a fragment of ammunition in all cases analysed, while entry and exit wounds were successfully analysed on the autopsy table. CT visualization following contact shots with .12 8.45 mm ammunition is presented in Figure 3.

The results of the present study confirm the usefulness of post-mortem computed tomography in each of the cases analysed. Images obtained during the analysis of each carcass revealed numerous comminuted bone

fractures and unquestionably facilitated subsequent necropsy with regard to the search for foreign bodies in the material. After precisely locating foreign bodies lodged in the material, it was possible to remove layers of tissue and secure even small fragments of ammunition, which usually constitute material evidence in a case.

The present study, as well as the results of observations by many researchers, including Skowronek and Chowanec (11), Kirchhoff et al. (2), Scaparra et al. (8, 9) and Woźniak et al. (22), underscores the informative value of imaging diagnostics while confirming that autopsy should remain the gold standard in forensic medicine and forensic veterinary medicine with regard to pathological and anatomical diagnostics and assessment, as well as in forensic expert opinions in cases associated with the shooting of a person or animal with a firearm.

The results of the experiment demonstrate that autopsy, as the gold standard in both human and veterinary forensics, is an extremely important preliminary element of expert opinions on gunshot injuries. In each case, autopsy should be the principal examination,

because it is an empirical assessment of pathological changes in the material. The macroscopic image of these changes, both morphological and biophysical, allows a wound to be classified as an entry wound or an exit wound, through which the projectile departed the material. It also makes it possible to analyse the skin surface, and the hair coat in the case of animals, with the accompanying fouling, burns or singed hair, as well as the presence of stippling from unburned gunpowder particles following a gunshot. The autopsy technique additionally offers the opportunity for tissue biopsy for further analysis, e.g. histopathological examination.

Williams et al. (19) conducted histopathological analysis of injuries following experimental shooting of rats. Using H&E staining,



**Fig. 4. Foreign bodies extracted from material during necropsy**

Explanations: A – structural element of a .12 2.45 mm cartridge, contact shot; B – structural element of a .12 8.45 mm cartridge, contact shot; C – fragment of a shot projectile (.12 2.45 mm contact shot) in subcutaneous tissue; D – metallic foreign body (.12 8.45 mm contact shot) and wound track; E – slug remains extracted after a contact shot; A, B – scale in cm.

they performed a morphological assessment of damage to structures in the contusion zone of the brain. It was impossible to obtain similar results in the present study because living models were not used in the experiment. The material evaluated in the experiment was stored in refrigerated conditions for a longer time; hence, due to regressive changes, the result of the histopathological examination is not reliable. In the case of shooting a living object, it would presumably be possible to obtain a histopathological image in tissues adjacent to the entry wound characteristic of the shock and destruction caused by the partial transfer of the energy carried by the penetrating ammunition to the tissues. Microscopic examination of biological material in veterinary forensics is used to verify whether questionable injuries took place in a living object and at what time. Therefore this method is very useful for determining whether the victim was shot while alive or post mortem. Post-mortem histopathological analysis involved determination of the degree of disintegration of tissues surrounding the entry wound (abrasion collar). Shots at a closer range were shown to cause much greater fragmentation of the epidermis and dermis than shots from further distances. Nevertheless, this method does not seem sufficiently specific for this type of injury, so its use for analysing post-mortem gunshot injuries in animals should be treated as experimental rather than as a useful additional analysis. Histopathological examination, however, is very useful for analysing gunshot residue in the vicinity of the entry wound, as confirmed by Tugcu et al. (16) and Turillazzi et al. (17).

Given the common occurrence of gunshots from hunting weapons in forensic veterinary practice and the need to establish the causes and effects of the event and to identify the ammunition used, it is important to know the characteristic features of injuries caused by various types of ammunition. The experiment carried out in this study, aimed at obtaining a wide-ranging picture of gunshot injuries to tissues struck by .12 ammunition with varying pellet diameters, made it possible to present in a clear manner the significant differences in images obtained, taking into account the diameter and body mass of the projectiles, as well as the distance from which the shot was fired. This is a basis for preparing a competent and reliable forensic veterinary expert opinion. It also systematizes knowledge on this subject, making it possible to select the most effective methods of analysis and thus guiding expert veterinarians and procedural authorities in the execution of their professional duties.

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